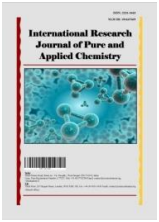

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Water Deficit Implication on the Growth Attributing Characters of Some Selected Improved Banana Germplasm under in an *Inseptisol* of North East India

Amarjit Saikia[1], Prakash Kalita[1], Soibam Helena Devi[1], Ingudam Bhupenchandra[2*], Laishram Kanta Singh[3], S. S. Bora[4], Seema Bhagowoti[5], Babita Tamuli[5], S. Roma Devi[6] and Kripal Bora[5]

[1]Department of Crop physiology, Assam Agricultural University, Jorhat, Assam, India.
[2]ICAR-KVK Tamenglong, ICAR-RC for NEH Region, Manipur Centre, India.
[3]ICAR-KVK Imphal West, ICAR-RC for NEH Region, Manipur Centre, India.
[4]ICRI, RRS, Spices Board, Tadong, Gangtok, India.
[5]Department of Soil Science, Assam Agricultural University, Jorhat, Assam, India.
[6]ICAR-KVK Churchandpur, ICAR-RC for NEH Region, Manipur Centre, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author AS did the conceptualization, methodology formulation and implementation. Author PK reviewed the study, did the rigorous editing of original and revised versions of the manuscript. Author SHD visualized reviewed and edited the manuscript. Author IB edited the manuscript, data analysis, author LKS prepared the original draft and revised the draft. Author SSB did the result compilation. Author SB prepare the manuscript. Authors BT, SRD and KB reviewed the compilation. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat during the year 2014-2016 with ten germplasm of banana *viz.* Gobin Tulchi (AAB), Bogimonohar (ABB), Manohar (AAB), Agnisagar (AAA). Barjahaji (AAA), Kachkal (ABB), Assamese Malbhog (AAB), Chenichampa (AAB), Bharatmoni (AAB) and Jahaji (AAA) to assess the physiological performance of this banana (*Musa* spp.) germplasm with special reference

**Corresponding author: E-mail: ibhupenj@gmail.com;*

to moisture stress. The various parameters were recorded at 5th, 7th and 9th months after planting. The soil of the experimental field was acidic, well drained and sandy loam in texture with low available N and K and medium available P content. The statistical design was Randomized block design. All the data pertaining to the present investigation were statistically analysed as per the method of analysis of variance (ANOVA) given by Panse and Sukhatme (1967). The critical difference (CD) values were calculated at 5 per cent probability level. For analysis software SPSS 7.5, Costat 6.3 and MS-excel were used. Moisture stress progressively reduced the values of leaf area, root biomass, specific leaf weight, fruit length, fruit circumference, duration of fruit filling, number of hands per bunch, number of finger per bunch, pulp-peel ratio and bunch weight. The germplasm Barjahaji was found to be higher yielder followed by Bogimonohar and Agnisagar whereas the cultivar Kachkal and Assamese Malbhog were found to be the lowest performer in this regard. From the above, it can be concluded that the cultivars Barjahaji, Bogimonohar and Agnisagar are physiologically more tolerant.

Keywords: Banana; fruit length; leaf area; root biomass; specific leaf weight; water deficit.

1. INTRODUCTION

The Banana is a plant of the tropics and subtropics, requiring hot and humid climate. In India, banana is grown in the regions from the humid tropics to humid sub tropics and semi-arid tropics and from the sea level up to an elevation of 2000 meters above MSL [1]. Large areas of the bananas are grown along the river basins and in other areas where water sources have been present. The most suitable climate is the one with warm moist weather, even rainfall throughout the year without strong winds. Broadly speaking, banana cultivation is widely practiced in areas with the 102 cm isohyet and the 15.5°C (60°F) winter isotherms which roughly coincides with 30° latitude in the N and S of the equator [1].

Assam, the gate way to North East India, covers a total geographical area of 78,438 Sq. Km. spreading over 35 districts with a population of 31,205,576. As per census of 2011, 77% of the population lives in the rural areas of the state. Agriculture and its allied activities play important role in the socio-economic development of the State of Assam as this sector is the major contributor to the State economy which provides livelihood to a significant proportion of the population of the state. About 90% of the Assam farmers belong to small and marginal groups, the average operational holding being 1.55 hectares. Amongst all fruits, the production of banana fruit is the highest in Assam covering an area of 51.51 thousand ha. The total production of banana in Assam is 837.02 thousand metric tonnes from an area of 51.51 thousand hectares with a productivity of 16.9 metric tonnes/ha. The major banana genotypes grown in the Assam are: 'Jahaji' (AAA) (Dwarf Cavendish), 'Malbhog' (AAB), Chenichampa, Bhimkal, Amrit Sagar, Kachkal (culinary cultivar), Athiya etc. Though banana production potential is high in Assam, the banana production is affected by soil moisture stresses during period between November to January. Water deficit is one of the most important environmental stresses affecting agricultural productivity around the world and may result in considerable yield reductions [2]. Bananas being the long duration crop (12-14 months), they may face abiotic stresses (soil moisture deficit) in its life cycle. The stress effects are manifested at the time of yield and the impact of stress varies with genomic group and exposure of particular growth stages with varied duration to the stress. Basically, bananas are water loving crop and are very sensitive to soil water deficit, as shown in numerous field [3]. Musa genotypes have exhibited differences in stomatal sensitivity based on the age of the leaf, and modulated by environmental factors such as irradiance, vapour pressure deficit (VPD) and soil-plant-water relations.

Therefore, there exists opportunities to increase the productivity of banana by growing some tolerant cultivars as well as ameliorating the deleterious effects of moisture shortage on banana growth and development.

2. MATERIALS AND METHODS

2.1 Details of the Experimental Site

The field experiment was conducted at the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat during the year 2014-2016. The experimental site was situated at 26°47′ N latitude and 94°12′ S longitude and at an elevation of 86.8 m above

mean sea level. The climatic condition of Jorhat city located within the Upper Brahmaputra Valley Agro Climatic Zone of Assam is characterized by a subtropical environment with hot-humid summer and relatively dry and cool winter. The average annual rainfall is about 1875 mm to 2146 mm which is unevenly distributed throughout the year. Normal monsoon rain starts from June and continues till September with the pre monsoon shower commencing from mid-March. The rainfall intensity reaches its peak during monsoon. The intensity of rainfall decreases from October reaching the minimum during December/January. The temperature reaches a maximum of 34-36°C during summer and the maximum of 7°C during winter.

The meteorological data during the period of investigation recorded at the Meteorological Observatory of Department of Agro-Meteorology, Assam Agricultural University, Jorhat are presented in Fig. 1.

2.2 Edaphic Background

The soil of the experimental site belongs to the order *Inceptisol* and has been derived from the alluvial deposits of the river Brahmaputra. The soil of the experimental field is acidic, well drained and sandy loam in texture. The chemical properties of the soil are presented in the Table 1.

2.3 Experimental Details

The experiment was laid out in Randomized Block Design (RBD) with ten varieties with the spacing of (2.1 x 2.1) m. The number of replication was three. Total area of the experimental site was 88.20 square meter and

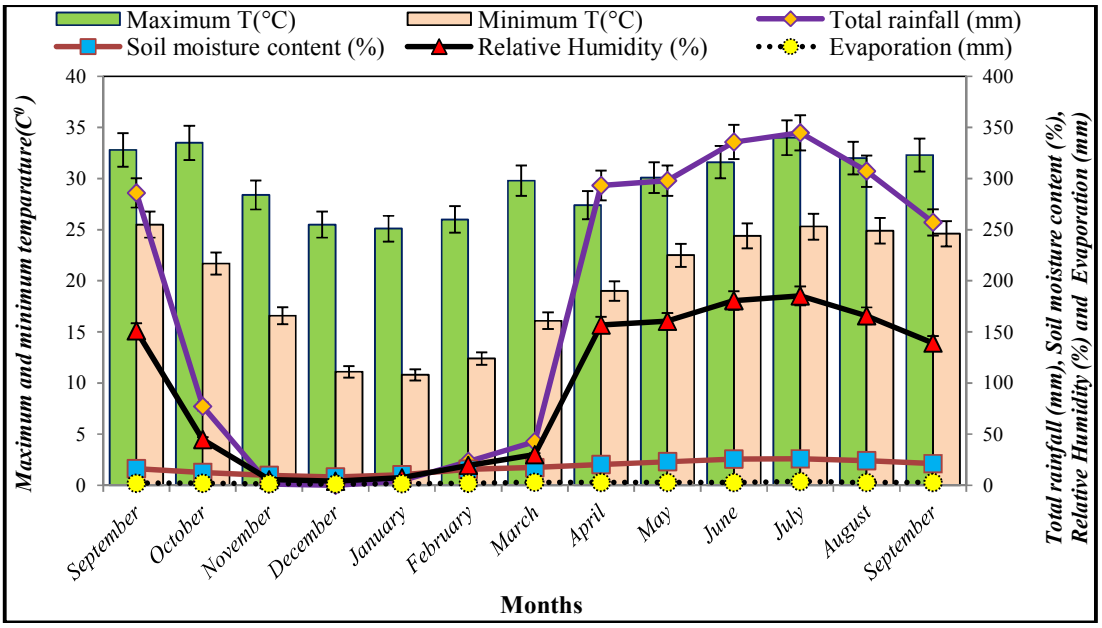

Fig. 1. Meteorological data during the period of field investigation during the year 2014-16

Table 1. Initial soil properties before

Particulars	Values (2014-2015)	Methods employed
pH	4.68	Glass Electrode Method [4]
Organic carbon (%)	0.56	Wet Digestion Method [5]
Available Nitrogen (kg ha^{-1})	200.45	Modified Kjeldahl's Method [4]
Available Phosphorus (kg ha^{-1})	40.76	Bray's Method [4]
Available Potassium (kg ha^{-1})	97.84	Flame Photometric Method [4]
Cation Exchange Capacity [cmol $(p+)kg^{-1}$]	6.80	Distillation Method [4]
Water Holding Capacity (%)	33.10	Keen Rackzowski Box Method [6]

the observations for various parameters were recorded on 5th, 7th and 9th months after planting. The germplasm are collected from the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat

Germplasm taken

1. Gobin Tulchi
2. Bogimonohar
3. Manohar
4. Agnisagar
5. Barjahaji
6. Kachkal
7. Assamese Malbhog
8. Chenichampa
9. Bharatmoni
10. Jahaji

2.4 Experimental Details of the Study Area

The experiment was laid out in a simple randomized block design with three replications.

2.5 Germplasm Collection

The germplasm were collected from the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat.

The germplasm taken for analysis were Gobin Tulchi, Bogimonohar, Manohar, Agnisagar, Barjahaji, Kachkal, Assamese Malbhog, Chenichampa, Bharatmoni and Jahaji. The antioxidative enzymes were estimated during 5th, 7th, 9th months after planting.

- **Leaf area:** Leaf area of the third fully expanded leaf from the apex was calculated by multiplying the product of the length and breadth of the lamina with the factor 0.8 [7] and expressed in unit of square meter. The length of the leaf was measured from the lamina base to its apex along the midrib and width was measured at the broadest portion of the lamina. The leaf area at 5th, 7th and 9th months after planting were determined.
  To compute the total leaf area of the plant the leaf area of the third leaf was multiplied by the number of functional leaves recorded in the individual plant at the time of observation [7].

- **Root biomass:** Root biomass is calculated as
  Root biomass = Fresh weight of root – Dry weight of root

- **Specific leaf weight of leaf:** Specific leaf weight (SLW) is calculated as leaf area/leaf weight of the third fully expanded leaf.

- **Fruit length:** Fruit length was measured using a thread from the base of the pedicel to the tip of the fruit along with the dorsal curve and expressed in centimeters.

- **Fruit circumference:** The fruit circumference was measured at the middle portion of the representative finger selected for finger length using a thread and expressed in centimeters.

- **Duration of fruit filling:** The duration of fruit filling was calculated as time taken from flowering to fruit development.

- **Number of hands per bunch:** The total number of fully developed hands per bunch was counted for each bunch.

- **Number of fingers per bunch:** Number of fingers per bunch was counted in the second hand.

- **Pulp-peel ratio:** Pulp-peel ratio was calculated by dividing the mean pulp weight by the mean of peel weight.

Pulp-peel ratio = Pulp weight (g) /peel weight (g)

- **Bunch weight:** The weight of the second hand was recorded and expressed in kilogram.

2.6 Collection and Preparation of Soil Sample

Soil samples were collected at a distance of 50 cm from the plant at a depth of 0-30 cm (Lopez, 1998). The soil samples so collected were air dried, ground with wooden roller and passed through 2 mm sieve and stored in butter paper bags with proper tagging and used for various analysis pertinent to the experiment.

2.7 Statistical Analysis

All the data pertaining to the present investigation were statistically analysed as per the method of analysis of variance (ANOVA)

outlined by Panse and Sukhatme (1967). The critical difference (CD) values were calculated at 5 per cent probability level. For analysis software SPSS 7.5, Costat 6.3 and MS-excel were used.

3. RESULTS AND DISCUSSION

3.1 Leaf Area

The data (Table 2) indicated that the leaf area per plant have showed significant variations among the germplasms. The time trend of leaf area revealed a gradual decrease from 5th to 7th MAP with a slight increase towards 9th MAP. At 5th MAP the highest leaf area was observed in Manohar (1.04 m^2) followed by Bogimanohar (1.03 m^2) and Kachkal (1.03 m^2), and the lowest was observed in Jahaji (0.77 m^2) and Bharatmoni (0.83 m^2). The germplasm Manohar registered 0.96 per cent higher leaf area over the Bogimanohar. At 7th MAP the highest leaf area was observed in Manohar (1.10 m^2) followed by Gobin Tulchi (0.87 m^2) and Kachkal (0.77 m^2), and the lowest was observed in Jahaji (0.57 m^2) and Assamese Malbhog (0.59 m^2). The germplasm Manohar registered 20.91 per cent higher leaf area over the Gobin Tulchi. At 9th MAP the highest leaf area was observed in Manohar (1.35 m^2) followed by Bogimanohar (1.15 m^2) and Chenichampa (1.13 m^2), and the lowest was observed in Jahaji (0.85 m^2) and Gobin Tulchi (0.89 m^2). The germplasm Manohar registered 14.81 per cent higher leaf area over the Bogimanohar. On an average, highest leaf area was recorded in Manohar (1.16 m^2) and lowest leaf area was observed in Jahaji (0.73 m^2).

Significant variation in amount of leaf area was recorded among the banana germplasm (Table 5). At 5th MAP the highest leaf area was observed in Manohar followed by Bogimanohar and Kachkal and the lowest was observed in Jahaji and Bharatmoni. The germplasm Manohar registered 0.96 per cent higher leaf area over the Bogimanohar. At 7th MAP the highest leaf area was observed in Manohar followed by Gobin Tulchi and Kachkal, and the lowest was observed in Jahaji and Assamese Malbhog. The germplasm Manohar registered 20.91 per cent higher leaf area over the Gobin Tulchi. On an average at 7th MAP the leaf area values were lower compared to that of 5th MAP which may be related to the lower soil moisture content at 7th MAP compared to 5th MAP. At 9th MAP the highest leaf area was observed in Manohar followed by Bogimanohar and Chenichampa, and the lowest was observed in Jahaji and Gobin Tulchi. The germplasm Manohar registered 14.81 per cent higher leaf area over the Bogimanohar. On an average at 9th MAP the germplasm of banana showed 29.80 per cent increase in leaf area compared to that of 7th MAP. On an average, among the ten banana germplasm Manohar showed highest leaf area followed by Kachkal, Bogimanohar, Agnisagar and Chenichampa. On the other hand Jahaji showed lowest leaf area followed by Assamese Malbhog, Bharatmoni, Gobin Tulchi and Barjahaji. In the present study Manohar registered 16.37 per cent increase in leaf area over Kachkal. In our present study the higher yielding germplasm like Barjahaji etc. maintain an intermediate value of leaf area as an adaptive mechanism to moisture deficit. Inhibition of leaf growth by water stress can be considered to be an adaptive response. Thus it limits leaf area production, plants rate of transpiration [8]. The banana plants sensitivity to soil moisture stress, reflected in changes in reduced growth through reduced stomatal conductance and leaf size leads to reduction in photosynthetic pigments [9]. Cotton plants when grown under dryland condition exhibited a decrease in leaf size per plant [10].

3.2 Specific Leaf Weight of Leaf (Mg/Cm2)

The variation in specific leaf weight of leaf of all the germplasm is depicted in Table 3. The results revealed a significant variation of specific leaf weight of leaf among all germplasm. At 9th MAP the highest specific leaf weight of leaf was found in Barjahaji (0.81 mg/cm^2) followed by Bogimanohar (0.79 mg/cm^2) and Agnisagar (0.78 mg/cm^2), and the lowest was found in Kachkal (0.63 mg/cm^2) followed by Assamese Malbhog (0.64 mg/cm^2). The germplasm Barjahaji registered 2.46 per cent higher SLWL over Bogimanohar. At 7th MAP the highest specific leaf weight of leaf was found in Barjahaji (0.74 mg/cm^2) followed by Bogimanohar (0.72 mg/cm^2) and Agnisagar (0.71 mg/cm^2), and the lowest was found in Kachkal (0.56 mg/cm^2) followed by Assamese Malbhog (0.57 mg/cm^2). The germplasm Barjahaji registered 2.7 per cent higher SLWL over Bogimanohar. At 9th MAP the highest specific leaf weight of leaf was found in Barjahaji (0.82 mg/cm^2) followed by Bogimanohar (0.80 mg/cm^2) and Agnisagar (0.79 mg/cm^2), and the lowest was found in Kachkal (0.64 mg/cm^2) followed by Assamese Malbhog (0.65 mg/cm^2). The germplasm Barjahaji

registered 2.43 per cent higher SLWL over Bogimanohar. On an average, it was recorded that in the germplasm Barjahaji (0.79 mg/cm^2) had the highest value of specific leaf weight of leaf and the lowest value was recorded in the germplasm Kachkal (0.61mg/cm^2). The per cent increase of specific leaf weight of leaf by Barjahaji was 2.53 per cent over Bogimanohar.

Specific leaf weight was found to be significantly affected by the germplasm (Table 3). Specific leaf weight (SLW), a measure of thickness of leaf, has been reported to have a positive correlation with leaf photosynthesis in several crops as reported by Bowes *et al.* (1972). In the present investigation at 9th MAP the SLW values were higher compared to 7th MAP. Here the highest SLW was found in Barjahaji followed by Bogimanohar and Agnisagar, and the lowest was found in Kachkal followed by Assamese Malbhog. The germplasm Barjahaji registered 2.46 per cent higher SLW over Bogimanohar. At 7th MAP the highest SLW was found in Barjahaji followed by Bogimanohar and Agnisagar, and the lowest was found in Kachkal followed by Assamese Malbhog. The germplasm Barjahaji registered 2.7 per cent higher SLW over Bogimanohar. At 9th MAP the highest SLW was found in Barjahaji followed by Bogimanohar and Agnisagar, and the lowest was found in Kachkal followed by Assamese Malbhog. The germplasm Barjahaji registered 2.43 per cent higher SLW over Bogimanohar. On an average at 9th MAP the germplasm of banana showed 10.95 per cent increase in SLW compared to that of 7th MAP. Mean data over the three stages of observation (*viz.*, 5th, 7th and 9th MAP) indicated that the highest value of SLW was recorded in Barjahaji followed by Bogimanohar, Agnisagar, Gobin Tulchi, Jahaji and Manohar. The lowest value of specific leaf weight was recorded in Kachkal followed by Bharatmoni, Chenichampa and Assamese Malbhog. In the present study Barjahaji registered 2.53 per cent higher values of SLW over Bogimanohar. The mechanism of maintaining higher specific leaf weight could be related to its thickness of leaves with more photosynthetic proteins per unit area of leaf [11].

3.3 Fruit Length (Cm)

The results of fruit length were displayed in the Fig. 2. There was a significant variation in fruit length was observed among all the germplasm. It was recorded that in the germplasm Barjahaji (22.58 cm) had the highest value of fruit length and the lowest fruit length was recorded in Chenichampa (12.38 cm). Among the germplasm the gradual decrease of fruit length was observed as Jahaji (19.2 cm), Agnisagar (18.75 cm), Manohar (17.94 cm), Kachkal (17.83 cm), Bogimanohar (17.45 cm), Gobin Tulchi (16.25 cm), Bharatmoni (13.75 cm) and Assamese Malbhog (12.58 cm). In the present study Barjahaji registered 14.96 per cent increase in fruit length over Jahaji.

Fruit length was found to differ significantly among the germplasm of banana (Table 4). The highest fruit length was found in Barjahaji followed by Jahaji, Agnisagar, Manohar, Kachkal, Bogimanohar, Gobin Tulchi. The lowest fruit length was recorded in Chenichampa followed by Bharatmoni and Assamese Malbhog.

Table 2. Leaf area (m^2) of ten germplasm of banana at 5th, 7th and 9th month after planting

Varieties	Leaf area(m^2)			
	5th	7th	9th	Mean
Gobin Tulchi	0.86	0.87	0.89	0.87
Bogimanohar	1.03	0.71	1.15	0.96
Manohar	1.04	0.73	1.35	1.16
Aagnisagar	1.01	0.74	1.12	0.96
Barjahaji	0.97	0.65	1.05	0.89
Kachkal	1.03	0.77	1.11	0.97
Assamese Malbhog	0.86	0.59	0.91	0.79
Chenichampa	1.01	0.64	1.13	0.93
Bhorotmoni	0.83	0.68	0.92	0.81
Jahaji	0.77	0.57	0.85	0.73
Mean	0.94	0.69	1.04	0.90
S.Ed(±)	0.004	0.014	0.003	
CD-5%	0.01	0.03	0.01	

Table 3. Specific leaf weight of leaf (mg/cm^2) of ten germplasm of banana at 5th, 7th and 9th month after planting

Varieties	Specific leaf weight of leaf (mg/cm^2)			
	5th	7th	9th	Mean
Gobin Tulchi	0.74	0.67	0.75	0.72
Bogimanohar	0.79	0.72	0.80	0.77
Manohar	0.72	0.65	0.73	0.70
Aagnisagar	0.78	0.71	0.79	0.76
Barjahaji	0.81	0.74	0.82	0.79
Kachkal	0.63	0.56	0.64	0.61
Assamese Malbhog	0.64	0.57	0.65	0.62
Chenichampa	0.67	0.60	0.68	0.65
Bhorotmoni	0.71	0.64	0.72	0.69
Jahaji	0.73	0.66	0.74	0.71
Mean	0.72	0.65	0.73	0.70
S.Ed(±)	0.004	0.002	0.07	
CD-5%	0.01	0.004	0.03	

Table 4. Fruit length and fruit circumference (cm) of ten germplasm of banana at harvest

Varieties	Fruit length (cm)	Fruit circumference (cm)
Gobin Tulchi	16.25	10.85
Bogimanohar	17.45	11.08
Manohar	17.94	12.41
Aagnisagar	18.78	12.30
Barjahaji	22.58	11.08
Kachkal	17.83	12.03
Assamese Malbhog	12.58	10.88
Chenichampa	12.38	10.90
Bhorotmoni	13.75	10.20
Jahaji	19.20	10.63
Mean	16.87	11.23
S.Ed(±)	0.222	0.243
CD-5%	0.46	0.81

In the present study Barjahaji registered 14.96 per cent higher values of fruit length over Jahaji. Banana cv. Williams in which bunch emergence occurred during a period of soil water stress (Ψs = -0.5 MPa) showed shorter fruits [12]. The maximum reduction in fruit length (11-14%) was observed at harvest when water stress was imposed at flowering [13].

3.4 Fruit Circumference (Cm)

Variation in fruit circumference among the germplasm are presented in Fig. 2. There was significant variation of fruit circumference. The highest fruit circumference was found in Manohar (12.41 cm) and the lowest fruit circumference was observed in Bharatmoni (10.2 cm). From the observation the gradual decrease of fruit circumference was recorded as Agnisagar (12.3 cm) and Kachkal (12.03 cm), Bogimanohar (11.08 cm), Barjahaji (11.08 cm), Chenichampa (10.90 cm), Assamese Malbhog (10.88 cm), Gobin Tulchi (10.85 cm) and Jahaji (10.63 cm). In the present study Manohar registered 0.88 per cent increase in fruit circumference over Agnisagar.

The data on fruit circumference was found to be significantly variable among the banana germplasm (Table 4). The highest fruit circumference was observed in Manohar followed by Agnisagar and Kachkal, Bogimanohar and Barjahaji. The lowest fruit circumference was observed in Bharatmoni followed by Chenichampa, Assamese Malbhog, Gobin Tulchi and Jahaji. In the present study Manohar registered 0.88 per cent higher fruit circumference over Agnisagar. The maximum reduction in fruit circumference (5.75-16%) was observed at harvest when water stress was imposed at flowering [13].

3.5 Number of Hands per Bunch

Number of hands per bunch was found to be significantly variable among the germplasm of banana (Fig. 2). Among all the ten germplasm the highest number of hands per bunch was observed in Barjahaji followed by Manohar, Jahaji, Chenichampa, Gobin Tulchi, Bogimanohar and Agnisagar. The lowest number of hands per bunch was observed in Assamese Malbhog followed by Bharatmoni and Kachkal. In the present study Barjahaji registered 8.57 per cent higher number of hands per bunch over Manohar. Murali et al. [14] studied the effect of soil moisture stress at different stages on yield and yield parameters of banana reported that highest fruit yield was obtained under no stress followed by stress at fruiting stage. Surendar et al. [15] studying the effect of water deficit on relationship between yield and physiological attributes of banana cultivars and hybrids reported that water deficit cause reduction in number of hands per bunch.

The data presented in Table 5 revealed that hands per bunch showed significant variation among the germplasm. Among the germplasm it has been observed that Barjahaji (8.75) showed the highest number of hands per bunch and the lowest number of hands per bunch was showed by Assamese Malbhog (5.5). Among all the ten germplasm the gradual decreasing number of hands per bunch was seen as Manohar (8), Jahaji (7.5), Chenichampa (7.25), Gobin Tulchi (7), Bogimanohar (7), Agnisagar (7), Bharatmoni (6.75) and Kachkal (5.75). In the present study Barjahaji registered 8.57 per cent increase in number of hands per bunch over Manohar.

3.6 Number of Fingers per Bunch

The variation in fingers per bunch in all the ten germplasm is depicted in Fig. 2. It was recorded that in Barjahaji (198.75) had the highest value of fingers per hand and the lowest value was recorded in Kachkal (61.75). From the observation the gradual decreasing numbers of fingers per bunch was recorded as Bogimanohar (154), Agnisagar (101.01), Chenichampa (97.75), Jahaji (87.75), Manohar (79), Bharatmoni (78.5), Gobin Tulchi (78.06) and Assamese Malbhog (67.75). In the present study Barjahaji registered 22.51 per cent increase in number of fingers per bunch over Bogimanohar.

The data on number of fingers per bunch was found to differ significantly among the germplasm of banana (Table 5). Among all the ten germplasm the highest number of fingers per bunch was observed in Barjahaji followed by Bogimanohar. It may be due to high relative water content in those germplasm which helps in better translocation of photosynthates to fingers for better filling. The lowest number of fingers per bunch was observed in Kachkal followed by Agnisagar, Chenichampa, Jahaji, Manohar, Bharatmoni and Gobin Tulchi. In the present study Barjahaji registered 22.51 per cent increase in number of fingers per bunch over Bogimanohar. Murali et al. [14] studied the effect of soil moisture stress at different stages on yield and yield parameters of banana and reported that highest fruit yield was obtained under no stress followed by stress at fruiting stage. Surendar et al. [15] studying the effect of water deficit on relationship between yield and

Table 5. Number of hands per bunch and number of fingers per bunch of ten germplasm of banana at harvest

Varieties	Number of hands/bunch	Number of fingers/bunch
Gobin Tulchi	7.00	78.06
Bogimanohar	7.00	154.00
Manohar	8.00	78.00
Aagnisagar	7.00	101.01
Barjahaji	8.75	198.75
Kachkal	5.75	61.75
Assamese Malbhog	5.50	67.75
Chenichampa	7.25	97.75
Bhorotmoni	6.75	78.50
Jahaji	7.50	87.75
Mean	7.05	100.43
S.Ed(±)	0.429	0.041
CD-5%	0.90	0.09

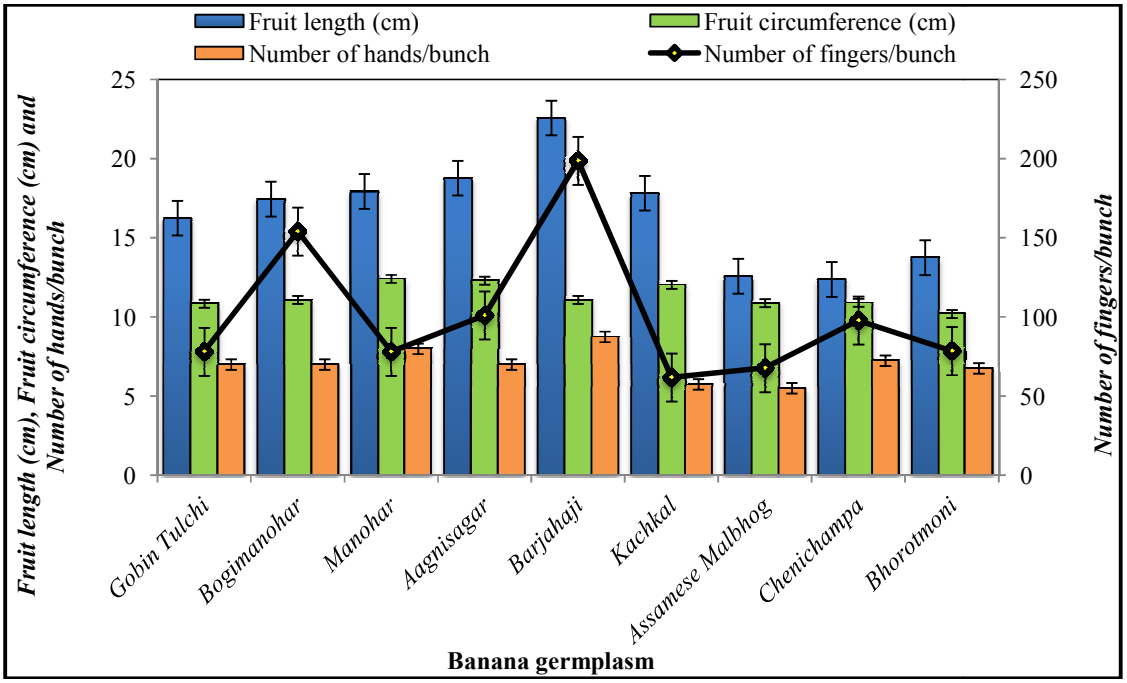

Fig. 2. Impact of water deficit on yield attributing parameters of different banana germplasm cultivation

physiological attributes of banana cultivars and hybrids reported that water deficit cause reduction in number of fingers per bunch.

3.7 Root Biomass (G)

The results of root biomass were displayed in the Table 4. There was a significant variation in root biomass among the germplasm were observed. It was recorded that in variety Barjahaji (480.33 g) had the highest root biomass and the lowest root biomass was recorded in Kachkal (267 g). The gradual decreasing trend of root biomass from the recorded data as Bogimanohar (453.33 g), Agnisagar (357.67 g), Jahaji (346 g), Chenichampa (334.33 g), Bharatmoni (316 g), Manohar (305.66g), Gobin Tulchi (281.66 g) and Assamese Malbhog (271 g). The germplasm Barjahaji registered 5.62 per cent higher root biomass over Bogimanohar.

The root biomass varied significantly among the banana germplasm (Table 6). Among the ten germplasm of banana Barjahaji and Bogimanohar showed higher root biomass followed by Agnisagar, Jahaji, Chenichampa, Bharatmoni and Manohar. The germplasm Barjahaji registered 5.62 per cent higher root biomass over Bogimanohar. This might be due to high accumulation of proline in leaves of those germplasm there by maintaining better water status in leaf allowing better photosynthesis and other metabolic processes. The lowest root biomass was recorded in Kachkal followed by Assamese Malbhog and Gobin Tulchi. The communication from Araya [16] provides data on the root distribution of several *Musa* genotypes in Central America. The total excavated fresh weight of roots varied from 0.8 kg for cv. 'Valery' (AAA, Cavendish subgroup) to more than 3.5 kg for cv. 'Yangambi km5' (AAA), showing the large difference in size of the root system between genotypes. In the present study Barjahaji registered 44.41 per cent increase in root biomass over Kachkal.

3.8 Pulp-Peel Ratio

Changes in pulp-peel ratio of fruit are shown in Table 5. The highest value was observed in Assamese Malbhog (4.35) and the lowest value was observed in the Chenichampa (1.7). The gradual decreasing value of pulp-peel ratio from the observation as Agnisagar (3.27), Manohar (3.01), Borjahaji (2.97), Gobin Tulchi (2.82), Kachkal (2.77), Jahaji (2.53), Barjahaji (2.43) and Bharatmoni (2). In the present study Assamese Malbhog registered 24.82 per cent increase in pulp-peel ratio over Agnisagar.

Table 6. Root biomass (g) of ten germplasm of banana at harvest

Varieties	Root biomass (g)
Gobin Tulchi	281.66
Bogimanohar	453.33
Manohar	305.66
Aagnisagar	357.67
Barjahaji	480.33
Kachkal	267.00
Assamese Malbhog	271.00
Chenichampa	334.33
Bhorotmoni	316.00
Jahaji	346.00
Mean	341.29
S.Ed(±)	1.183
CD-5%	2.48

Water deficit cause significant change in pulp-peel ratio among the banana germplasm (Table 7). Among all the germplasm the highest pulp-peel ratio was observed in Assamese Malbhog followed by Agnisagar and Manohar. The lowest pulp-peel ratio was observed in cultivar Chenichampa followed by Bogimanohar, Gobin Tulchi, Kachkal, Jahaji, Barjahaji and Bharatmoni. In the present study Assamese Malbhog registered 24.82 per cent higher in pulp-peel ratio over Agnisagar. Baruah et al. [17] observed that in terms of pulp-peel ratio 'Assamese Malbhog' showed the highest value (4.35) which were closely followed by 'Garomaina' (4.34) and Amritsagar (4.01).

3.9 Duration of Fruit Filling (Days)

Changes in duration of fruit filling among the germplasm are shown in Table 7. The highest duration of fruit filling was seen in the germplasm Chenichampa (95 days) and the lowest duration of fruit filling was found in Bharatmoni (53.5 days). Among the germplasm the decreasing pattern of duration of fruit filling was observed as Assamese Malbhog (82.5 days), Manohar (82 days), Gobin Tulchi (72 days), Jahaji (70 days), Agnisagar (70 days), Bogimanohar (69.78), Kachkal (59.5 days) and Barjahaji (57.5 days). In the present study Chenichampa registered 13.15 per cent increase in duration of fruit filling over Assamese Malbhog.

The data on duration of fruit filling was significantly influenced among the germplasm (Table 7). The highest duration of fruit filling was observed in Chenichampa followed by Assamese Malbhog, Manohar, Gobin Tulchi, Jahaji and Agnisagar. The lowest duration was observed in Bharatmoni followed by Bogimanohar, Kachkal and Barjahaji. In the present study Chenichampa registered 13.15 per cent increase in duration of fruit filling over Assamese Malbhog. Banana cv. Williams in which bunch emergence occurred during a period of soil water stress (Ψs = -0.5 MPa) exhibited longer duration of fruit filling [12].

3.10 Bunch Weight

Variation in bunch weight among the germplasm are presented in Table 8. There was significant variation of bunch weight among the germplasm. The highest bunch weight was found in Barjahaji

Table 7. Pulp-peel ratio and duration of fruit filling (days) of ten germplasm of banana at harvest

Varieties	Pulp-peel ratio	Duration of fruit filling (days)
Gobin Tulchi	2.82	72.00
Bogimanohar	2.97	69.78
Manohar	3.01	82.00
Aagnisagar	3.27	70.00
Barjahaji	2.43	57.50
Kachkal	2.77	59.50
Assamese Malbhog	4.35	82.50
Chenichampa	1.70	95.00
Bhorotmoni	2.00	53.50
Jahaji	2.53	70.00
Mean	2.78	71.17
S.Ed(±)	0.078	0.382
CD-5%	0.16	0.80

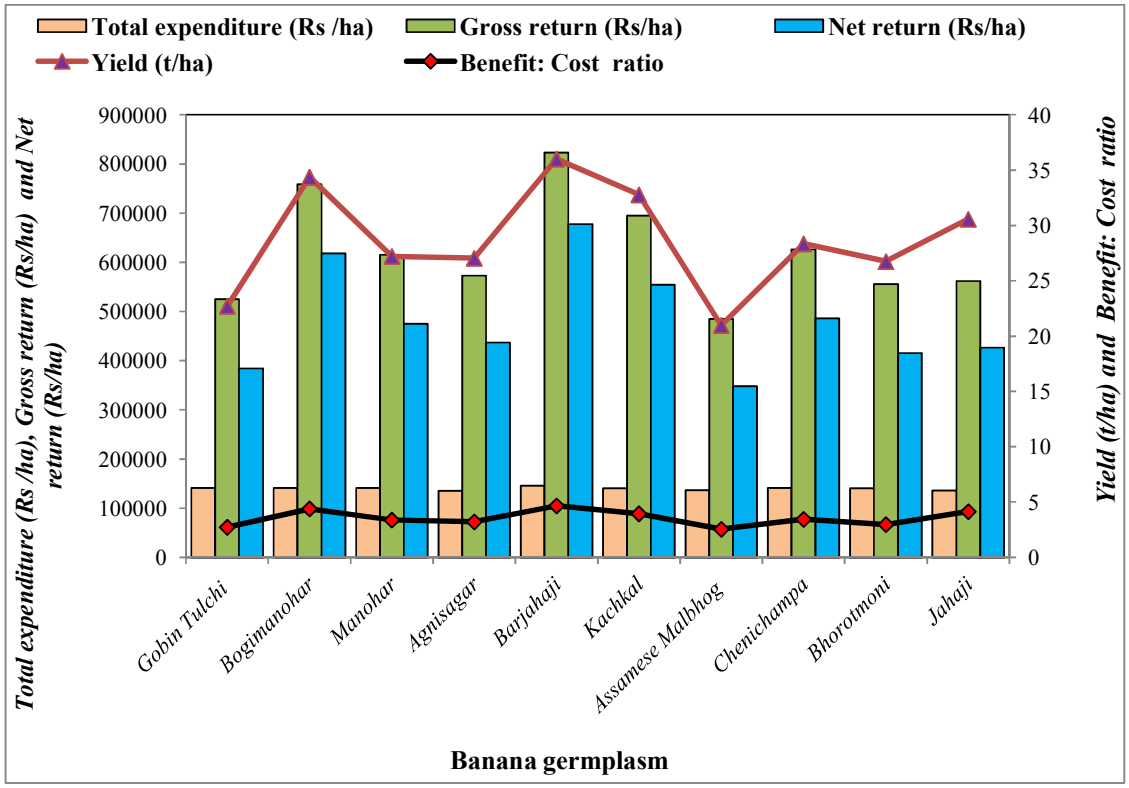

Fig. 3. Economic analysis of different banana germplasm cultivation grown under water stress

Return (fruit): Rs. 2000.00/ton
Sale price of sucker: Rs. 20.00/sucker

(15.88 kg) and the lowest in Assamese Malbhog (9.25 kg). Among the germplasm the decreasing pattern of bunch weight was found as Bogimanohar (15.16 kg), Kachkal (14.46 kg), Jahaji (13.49 kg), Chenichampa (12.50 kg), Manohar (12.00 kg), Agnisagar (11.93 kg), Bharatmoni (11.80 kg) and Gobin Tulchi (10.01 kg). In the present study Barjahaji registered 4.53 per cent increase in bunch weight over Bogimanohar.

Bunch yield of banana is considered as the major contributing factor for the final plant yield. From the experiment it was seen that bunch weight varied significantly among the germplasm (Table 8). Among the germplasm the highest bunch weight was found in Barjahaji followed by Bogimanohar, Kachkal, Jahaji, Chenichampa and Manohar. The lowest bunch weight was found in Assamese Malbhog followed by Gobin Tulchi, Bharatmoni and Agnisagar. In the present study Barjahaji registered 4.53 per cent higher in bunch weight over Bogimanohar. Turner and Rosales [18] also recorded a reduction in bunch yield due to water deficit.

Table 8. Bunch weight (kg Bunch^{-1}) of ten germplasm of banana at harvest

Varieties	Bunch weight (kg Bunch^{-1})
Gobin Tulchi	10.01
Bogimanohar	15.16
Manohar	12.00
Aagnisagar	11.93
Barjahaji	15.88
Kachkal	14.46
Assamese Malbhog	9.25
Chenichampa	12.50
Bhorotmoni	11.80
Jahaji	13.49
Mean	12.64
S.Ed(±)	0.063
CD-5%	0.09

4. ECONOMICS

Economics is the most important single factor which decides the adoption of any improved practices by the grower. A practice should not only be effective but also should be profitable

proposition to be accepted by the grower. In this study (Fig. 3), the different germplasm showed clear impact on the comparative economics of the production. The grand total expenditure was found comparatively higher in the germplasm Barjahaji followed by Gobin Tulchi and lowest in Agnisagar. The highest gross return of Rs. 8,23,325.52/ha was obtain in Barjahaji which resulted in the highest net return of Rs. 6,77,793.68/ha corresponding to the highest Benefit :cost ratio of 4.66. The other germplasm resulted lower gross return as well as benefit: cost ratio because of lower yield.

Total expenditure (Rs. /ha)

Cost of land preparation + cost of planting material + cost of planting + cost of manures and fertilizer + cost of intercultural operation + cost of plant protection chemicals + + harvesting cost.

5. CONCLUSION

The final yield of a crop is the cumulative effects of growth attributes which manipulate the favourable parameters could result in the positive relationship with higher productivity. The germplasm Barjahaji was found to be the highest yielder followed by the germplasm Bogimanohar and Agnisagar whereas Assamese Malbhog and Kachkal were found to be the lowest performers in this regard. Germplasm *viz.,* Barjahaji, Bogimanohar etc. recorded higher values for various characters namely leaf area, root biomass, specific leaf weight of leaf, fruit length, fruit circumference, duration of fruit feeling, number of hands per bunch, number of fingers per hand etc. This higher efficiency in terms of physiological and yield parameters in the germplasm namely Barjahaji, Bogimanohar etc. might have contributed immensely towards realization of the bunch weight per plant under Assam condition which faces severe shortage in soil moisture under rainfed situation during the months of winter mostly coinciding the reproductive stage of the crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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